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Memorandum

To: Matt McClincy, Oregon DEQ

From: John Edwards, RG, CEG, Anchor Environmental, L.L.C.

CC: Bob Wyatt, NW Natural and Carl Stivers, Anchor Environmental, L.L.C.

Date: December 19, 2005

Re: Preliminary Identification of Technologies and Alternatives for Groundwater Source Control, NW Natural Gasco Site, Portland, Oregon

1 INTRODUCTION

As requested in the Oregon Department of Environmental Quality's (DEQ) August 2, 2005 and September 15, 2005 letters, NW Natural has completed the first step in conducting a Groundwater Source Control Focused Feasibility Study (GWFFS) to evaluate source control technologies for dissolved chemicals in groundwater. As required by DEQ's November 23, 2005 letter, this evaluation addresses groundwater discharging to the Willamette River across both the Gasco and Siltronic facilities (the "Site"), although operational areas of the former Portland Gas & Coke manufactured gas plant extended only approximately 400 feet onto the current Siltronic facility (Figure 1). This technical memorandum identifies the groundwater source control technologies that are applicable for future evaluation in the GWFFS. DEQ's letters require that these technologies be screened and developed into alternatives for use in the GWFFS.

Based on our recent work for this memorandum and other technical memoranda (particularly the *Offshore Groundwater Sampling Approach* [Anchor 2005]), it is our technical judgment that the existing data are sufficient to identify general source control alternatives, but inadequate to screen out specific technologies, such as groundwater treatment method. This memo therefore identifies several general source control technologies, such as groundwater containment and treatment; then combines the technologies into five general source control alternatives for further evaluation in the GWFFS.

Concurrent with the GWFFS, NW Natural is conducting a Source Control DNAPL Focused Feasibility Study (FFS) to evaluate source control measures for dense non-aqueous phase liquid (DNAPL) located in the MW-16 Area adjacent to the Willamette River at the Site. The memorandum *Preliminary Identification of Technologies and Alternatives, DNAPL Focused Feasibility Study MW-16 Area, NW Natural Gasco Site* (Hahn and Associates, Inc.) was submitted to DEQ on September 26, 2005. Some of the same technologies that could be used to control dissolved chemicals in groundwater could also be effective for DNAPL mitigation, so the development of the GWFFS and DNAPL FFS will be closely coordinated. Technologies that would contain, remove, or treat DNAPL at the Site are not identified in this memorandum.

This memorandum provides background information only as necessary to identify technologies for groundwater source control at the Site. More detailed information on Site hydrogeology and the nature and extent of dissolved chemicals of interest (COIs) in groundwater are presented in the *Report on Supplemental Upland Remedial Investigation Activities* (HAI 2005) and the *Updated Phase I Site Characterization Summary Report* (HAI 2005)..

NW Natural plans to conduct an investigation of the nature and extent of COIs in the offshore transition zone and in groundwater below the river channel. That investigation is designed to provide information needed for the GWFFS. The *Offshore Groundwater Field Sampling Approach, Gasco/Siltronic Groundwater Source Evaluation* (Anchor 2005) has been submitted for DEQ review.

The sections of this memorandum, Preliminary Identification of Technologies and Alternatives for Groundwater Source Control are organized similar to the chapters of the *Preliminary Identification of Technologies and Alternatives DNAPL Focused Feasibility Study MW-16 Area, NW Natural Gasco Site* (HAI 2005). Additionally, the various control and treatment technologies are organized similarly in the two documents to facilitate review and future coordination of the GWFFS and DNAPL FFS.

2 BACKGROUND AND PRELIMINARY SCREENING

NW Natural and Siltronic Corporation own adjacent properties along the west shoreline of the Willamette River. Manufactured gas plant (MGP)-related COIs are present in groundwater on portions of both properties. The latest documentation of remedial investigation findings for the NW Natural Site is in the *Report On Supplemental Upland Remedial Investigation Activities* (HAI 2005). Siltronic Corporation's latest findings are in the report *Results of In-River Sediment and Groundwater Investigation, Siltronic Corporation* (Maul, Foster, Alongi, Inc. 2005) and *Supplemental Investigation Report* (Maul, Foster, Alongi, Inc. 2005). The results of further evaluation of data on the Siltronic property is presented in the *Updated Phase I Site Characterization Summary Report, Siltronic Corporation Property, 7200 NW Front Avenue, Portland, Oregon* (HAI 2005). This technical memorandum does not address Siltronic-related groundwater COIs, such as TCE.

The NW Natural and Siltronic Corporation investigations have assessed the nature and extent of upland groundwater contamination to provide data needed to conduct source control evaluations for the protection of beneficial uses of the Willamette River. The DEQ and Region 10 EPA issued the Interim Final Portland Harbor Joint Source Control Strategy (JSCS) in September 2005. The primary purpose of the JSCS is to provide a framework for making upland source control decisions at the Portland Harbor Superfund Site.

In order to identify potential source control technologies that are feasible for the Site, it is necessary to identify the specific chemicals in groundwater that may present unacceptable risk to beneficial uses of the river. Because different COIs have unique chemical and physical properties, they also have widely varying fate and transport characteristics in groundwater. Therefore, different groundwater source control and treatment technologies could be required for MGP COIs from Gasco operations, depending upon the suite of COIs that are targeted for source control.

The groundwater quality data from the NW Natural and Siltronic Corporation remedial investigations were reviewed for the purpose of developing a shortlist of target chemicals to consider for potential source control. The Preliminary Draft Offshore Groundwater Field Sampling Approach (Anchor, 2005) included a screening of the Gasco and Siltronic groundwater quality data for all COI against the lowest concentration ecological and human health criteria in the JSCS. Appendix B from that document contains the tables that resulted from the screening effort. Appendix A of this memo contains tables A1 through A5; these tables screen all of the JSCS criteria against all of the shoreline area COI groundwater quality data from the Surficial Fill and Alluvial Water Bearing Zones. The Site groundwater quality data in Appendix A are from monitoring wells and exploratory borings located in the study area boundary shown on Figure 2.

Because of their size, the five Appendix A tables are provided on a CD enclosed with this memo. The tables use shading to indicate which groundwater samples exceed each of the screening criteria, and symbols are used to identify which of the criteria are exceeded. The tables are considered preliminary at this time, and will be verified for accuracy and completeness when the JSCS is finalized by the DEQ and EPA.

In order to focus this technical memorandum on the identification of the most relevant potential source control alternatives, the remedial investigation data were reviewed to identify chemicals for further evaluation that meet two criteria. The first criterion was to identify chemicals with concentrations in groundwater that would likely exceed risk-based action levels if those concentrations occurred in the river (as summarized in Anchor 2005). The second criterion is that the shortlisted COI has similar physical and chemical properties to other COIs that might be targeted for source control. The idea is to identify a short list of chemicals that represent the classes of chemicals that will likely be targeted for source control.

Using this process the following four chemicals were identified for further evaluation.

- Naphthalene
- Benzo(a)pyrene
- Benzene
- Cyanide

Naphthalene and benzo(a)pyrene represent the range of PAHs (in terms of solubility in water) that could be targeted for source control. Source control technologies applicable to benzene would also likely be effective for the other BETX (benzene, ethylbenzene, toluene, and xylene) compounds and possibly for other volatile organic chemicals (VOCs). Technologies suitable for the PAHs and VOCs may not be suitable for cyanide, so it is included for further assessment. This shortlist of chemicals may change depending upon the results of additional planned investigations to be conducted on or near the NW Natural and Siltronic facilities.

3 SOURCE CONTROL OBJECTIVES

Before Site specific risk-based source control objectives can be developed, additional information is needed regarding the nature and extent of concentrations of chemicals of interest in offshore areas. This data is essential for identifying potential risk-based concentration goals. In the absence of site specific risk-based source control objectives, NW Natural proposes to use essentially the same generic objectives identified in the Preliminary Identification of Technologies and Alternatives DNAPL Focused Feasibility Study MW-16 Area (HAI 2005). The three source control objectives from the DNAPL FFS, modified for groundwater, are listed below.

- Prevent or reduce the potential for future migration of selected dissolved phase COI to the river at concentrations that may pose unacceptable risk
- Be compatible with the final remedy and other source control objectives
- Be consistent with current site use and potential future site redevelopment

NW Natural will develop specific source control objectives based upon the data to be collected in the proposed *Offshore Groundwater Field Sampling Approach, Gasco/Siltronic Groundwater Source Evaluation*, and by the Lower Willamette Group. NW Natural and DEQ must reach agreement on specific objectives before design and implementation of source control can proceed.

3.1 Phased Source Control

The water quality data in Appendix A show that the lowest concentration DEQ human health and ecological groundwater SLVs are exceeded along the entire shoreline of Gasco and Siltronic, based on groundwater data from monitoring wells and testing of groundwater grab samples from Geoprobe borings. The magnitude of exceedance of the SLVs is highest in the shoreline reach that extends approximately from the area of NW Natural well MW-3 to Siltronic well WS-12. This is illustrated in Figures 3 through 8, which show the magnitude of Benzene, Cyanide, and Naphthalene exceedances of the lowest human health and ecological SLVs along the Gasco and Siltronic shorelines.

NW Natural proposes to identify this reach of shoreline, from MW-3 to WS-12, as the zone of primary groundwater source control for the GWFFS. The boundaries of the primary source control zone will likely be modified as the GWFFS proceeds, but this preliminary identification of the boundary is sufficient to continue with the GWFFS. The primary source control zone generally coincides with the highest concentration of MGP sourced COIs and is generally downgradient of previously identified disposal areas of MGP derived materials, such as the former tar ponds.

The primary source control zone is generally identified as appropriate for evaluation of active source control using the technologies identified later in this memorandum. However, some areas of the shoreline outside of the primary source control zone contain dissolved COI concentrations that are orders of magnitude lower than the concentrations in the primary zone, and these zones may not require active source control. These areas may be found to not require source controls based on the weight of evidence approaches discussed in the JSCS. Alternatively, these areas may be suitable for a final remedy based upon monitored natural attenuation (MNA).

The area of the Gasco shoreline downriver of MW-3 and the portion of the Siltronic shoreline upriver of WS-12 are proposed to be designated as secondary source control areas that require further evaluation before the need for risk-based active source control measures can be determined. There are currently insufficient offshore data to determine if the upland groundwater concentrations in these areas are resulting in offshore impacts to river beneficial uses. As the data from the planned NW Natural and LWG offshore investigations are assessed, the boundaries of the primary and secondary source control zones can be adjusted.

NW Natural plans to aggressively pursue the evaluation of active source control options in the primary source control area. This will be done in the GWFFS on a parallel track with the DNAPL source control evaluation.

The GWFFS will include a concurrent evaluation of data from the NW Natural and LWG offshore investigations; with a schedule goal of determining if any portions of the secondary source control zone require active source control by the completion of the LWG in-water risk assessment.

3.2 Information Gaps to Define Primary and Secondary Source Control Zones

The concentrations of target chemicals from upland groundwater, through the transition zone, and into surface water have not been directly measured at this time. This information is needed to refine the boundaries of the primary and secondary source control zones identified in section 3.1 and to develop source control compliance objectives. Anchor performed extensive modeling of this process, which has been reported previously (Anchor 2001). Based on the modeling and the groundwater information available at the time, no groundwater COIs are expected to exceed AWQC concentrations upon reaching surface water. Common types of biogeochemical reactions that impact contaminant transport across the transition zone include acid-base reactions, precipitation and dissolution of minerals, sorption and ion exchange, oxidation-reduction reactions, increased biodegradation, and dissolution and exsolution of gases. In addition, it is widely recognized that as groundwater approaches surface water, surface water exchange takes place and can cause reductions in chemical concentrations within the transition zone (Boudreau 1997 and DiToro 2001). The offshore groundwater investigation currently proposed by NW Natural (Anchor 2005) will provide some of the data needed to assess chemical concentrations through the transition zone.

The suitability of many of the potential control technologies, such as slurry walls and in-situ chemical treatment cannot be fully evaluated until we have defined the dimensions of the offshore groundwater zone that exceeds risk-based criteria. The offshore groundwater investigation currently proposed by NW Natural will provide additional data needed to address these issues.

4 IDENTIFICATION OF TECHNOLOGIES

Table 1 lists groundwater source control technologies that appear suitable for further evaluation. All but one of the technologies listed in Table 1 represent some form of active source control that could be suitable in the Site primary source control zone identified in Section 3. Monitored Natural Attenuation (MNA) may be applied in Secondary Source Control Zones where dissolved concentrations of COI in upland groundwater do not result in impairment of in-river beneficial uses.

As described in the introduction; concurrent with the GWFFS, NW Natural is conducting a Source Control DNAPL Focused Feasibility Study (FFS) to evaluate source control measures for DNAPL located in the MW-16 Area adjacent to the Willamette River at the Site. Technologies that synergistically deal with both groundwater and DNAPL will be closely considered following the development of Site specific risk-based cleanup goals.

Table 1
Gasco Preliminary List of
Groundwater Source Control Technologies

Technology	PAH + Benzene	Cyanide
Containment		
Physical Barriers (slurry walls/sheet piles)	Yes	Yes
Groundwater Pumping	Yes	Yes
In Situ Biological Treatment		
Enhanced Biodegradation	Yes	Dissociable Cyanide
Natural Attenuation	Yes	Dissociable Cyanide
In Situ Physical/Chemical Treatment		
Chemical Oxidation	Yes	Dissociable Cyanide
Horizontal Wells (enhancement)	Yes	Yes
Dual Phase Extraction	Yes	No
Thermal Treatment	Yes	Yes
Recirculating Groundwater Recovery Wells	Yes	No
Soil Vapor Extraction/Air Sparging	Yes	No
Stabilization /Fixation	Yes	Yes
Containerized Recovery of Oily Wastes (CROW™)	Yes	Yes
Ex-Situ Biological Treatment		
Bioreactors	Yes	Dissociable Cyanide
Ex-Situ Physical/Chemical Treatment		
Adsorption/Absorption	Yes	Yes
Ion Exchange	No	Yes
Advanced Oxidation	Yes	Yes
GAC/Carbon Adsorption	Yes	Yes
Thermal Hydrolysis	Yes	Yes
Monitored Natural Attenuation	Yes	Yes

4.1 Containment

Containment of dissolved groundwater contaminants could be a component of future source control at the Site. Containment technologies are suitable for reducing the mass flux of contaminants past a designated point, but do not treat or destroy the contaminants. Some of the proven groundwater containment technologies have some potential for application at the Site: including passive low-permeability flow barriers like slurry walls; and hydraulic containment systems, such as pumping wells and interceptor trenches.

Extraction wells could be used to control dissolved COIs at the Site. The wells would be used to reverse the groundwater hydraulic gradient away from the river. Extraction wells would have to be designed to prevent cross contamination between the Surficial Fill and Alluvial Aquifers. The extraction wells would also be designed to work concurrently with the MW-16 NAPL control system. An extraction well system could be used in conjunction with a vertical flow barrier, such as a slurry wall; or designed to control groundwater flow without the use of a barrier.

Because there are no continuous aquitards along the Gasco shoreline, the use of low-permeability flow barriers alone will not likely be feasible. This is because the groundwater contaminant plume could flow under or around the slurry wall or other barrier, unless the base of the barrier is founded in an aquitard. Even without a shallow aquitard, it may be feasible to couple a low-permeability barrier with hydraulic containment, such as interceptor wells. In this application the wells would be placed on the upland side of the barrier to prevent the plume from bypassing the barrier.

Containment technologies may also be joined with in-situ or ex-situ treatment technologies, such as groundwater pumping combined with in-situ or ex-situ treatment.

Any groundwater containment technology considered for use at the Site will also be evaluated to determine how it could enhance or support future efforts to mitigate the upland DNAPL.

4.2 In-Situ Treatment

All in-situ treatment technologies have a shared technical limitation, which is related to the hydrogeological conditions in the subsurface zone of groundwater contamination. The success of all in-situ treatment methods depends upon achieving complete contact of the introduced chemicals or bacteria with the contaminated subsurface soil and groundwater. Some technologies require multiple subsurface applications of introduced materials to be effective. Remedial investigations completed to date at the Gasco and Siltronic facilities have shown that the subsurface fill and underlying alluvial soil are heterogeneous, with discontinuous, interbedded silt and sand layers. The interbedded layers would likely make uniform subsurface application of treatment chemicals, nutrients, or bacteria difficult, if not infeasible. However, in-situ options should not be discounted at this stage of the evaluation, based strictly on the heterogeneous nature of the Site subsurface materials. Therefore, the next two sections identify some of the proven technologies that could apply to the target analytes identified for the Site.

The presence of DNAPL at the Site is a major factor to be considered when evaluating the effectiveness of in-situ treatment technologies for dissolved contaminants. If the DNAPL cannot feasibly be completely removed from upland source areas, it could be a continuous source of dissolved contamination that could make in-situ remediation of dissolved contaminants infeasible. Under that circumstance, groundwater containment technologies, coupled with ex-situ groundwater treatment, would likely be the feasible remediation approach for dissolved groundwater contaminants.

4.2.1 In-Situ Biological Treatment

Natural attenuation by indigenous Site subsurface bacteria is likely ongoing, but has not been evaluated to date. This would likely be most effective in subsurface zones with lower contaminant concentrations that are not lethal to the bacteria, and would likely not be significant in areas adjacent to DNAPL. Enhanced biodegradation of certain PAH compounds, benzene, and dissociable cyanide is possible.

4.2.2 In-Situ Physical and Chemical Treatment

Table 1 lists eight in-situ technologies. The technologies have been proven effective at treating selected PAH compounds and/or benzene. Certain of the persistent PAH compounds, such as benzo(a)pyrene, would be the most recalcitrant to in-situ treatment methods. Four of the in-situ technologies, stabilization/fixation, CROW™, chemical oxidation, and recirculating groundwater recovery wells, may be effective for in-situ cyanide treatment. The CROW™ process may be applicable for simultaneous removal of DNAPL and dissolved contaminants.

Horizontal wells are included in the list as a potential enhancement for introducing treatment chemicals into the subsurface. Horizontal wells can be useful for introducing treatment chemicals into specific subsurface zones that cannot be easily accessed using traditional vertical wells, or for reaching subsurface zones where buildings or utilities preclude installation of vertical wells.

Recirculating groundwater recovery wells are constructed with a lower intake screen to draw in groundwater and an upper screen to pump the groundwater back into the formation. Continuous pumping using the lower and upper screens creates a zone of circulation within the aquifer that surrounds the well. Depending upon the target contaminants, the well casing is used for air stripping and/or the injection of nutrients, bacteria, or treatment chemicals that are circulated in-situ within the aquifer treatment zone.

4.3 Ex-Situ Treatment

Ex-situ treatment occurs in an above-ground treatment system. Ex-situ treatment of dissolved contaminants in groundwater could be a component of a hydraulic containment system as discussed in Section 4.1, or ex-situ treatment could be part of a DNAPL remediation alternative. Table 1 lists a number of general treatment technologies that could be effective for all of the target analytes.

4.3.1 Ex-Situ Biological Treatment

Ex-situ biological treatment using an above-ground bioreactor could be effective for treatment of benzene, some of the PAH compounds, and dissociable cyanide, but would be less effective for other cyanide complexes and the persistent PAH compounds, such as benzo(a)pyrene.

4.3.2 Ex-Situ Physical/Chemical Treatment

Ex-situ treatment systems can have multiple stages designed to handle chemicals with widely varying properties. Table 1 is not intended to include all of the treatment technologies that could be combined to handle all of the target analytes, but instead lists some representative technologies that could be effective for all of the target analytes.

The adsorption/absorption treatment category covers multiple adsorption media, except ion exchange and carbon adsorption which are listed separately. In addition to adsorption, the target analytes may be amenable to treatment by advanced oxidation methods and thermal hydrolysis.

4.4 Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) relies on natural subsurface attenuation processes to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods (EPA 1999). Natural attenuation processes active in the MNA approach include physical, chemical, or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and groundwater. MNA is a component of remediation programs at many sites nationwide, especially sites contaminated with petroleum fuels and solvents. Source control technologies that are feasible for reducing the mass discharge from the Site upland to the river may not be feasible for some areas beyond the transition zone. Natural attenuation of dissolved contaminants through groundwater flow advection and dispersion is assumed to be occurring at the Site; however, the presence of other attenuation processes, such as adsorption and biodegradation is unknown at this time. MNA will be considered as a potential component of the final cleanup plan for the Site.

5 GROUNDWATER SOURCE CONTROL ALTERNATIVES

The source control technologies identified in Table 1 have been further evaluated to develop some general groundwater control alternatives that could be applied at the Site. The alternatives were developed by combining the technologies that appear potentially suitable for Site conditions based upon Anchor's experience at similar sites and upon a review of technologies used at similar sites nationwide. This identification process is not intended to replace the traditional feasibility study evaluation of technology cost, implementability, and effectiveness; which will occur later in the GWFFS.

Five general groundwater source control (GWSC) alternatives have been identified for further evaluation in the GWFFS. Four of these alternatives are active control options that would prevent or reduce the migration of groundwater COIs to the river. These four alternatives will be carried forward for further consideration for the proposed primary source control zone. The fifth alternative, MNA, will be considered for those reaches of the shoreline where active source control is not needed.

GWSC-1 Shoreline Extraction Wells

- Screened at varying depths to create capture and avoid cross contamination between aquifer zones
- Consider combining with NAPL options at MW-16 area
- Ex-situ treatment of recovered groundwater
- NPDES discharge of treated water
- Possible vapor phase treatment required

GWSC-2 High Concentration Area and Shoreline Extraction Wells

- High concentration area upland wells to create capture and focus on NAPL areas
- Shoreline wells in high concentration areas
- Screened at varying depths
- Ex-Situ treatment and NPDES discharge
- Possible vapor phase treatment

GWSC-3 Shoreline Barrier Wall with Extraction Wells

- Approx 80 ft deep wall to reduce mass flux to river
- Extraction wells to prevent wall bypass
- Pumping rates significantly lower than alternatives GWSC-1 and 2, due to presence of barrier wall
- Wells screened at varying depths
- Ex-Situ Treatment and NPDES discharge
- Possible Vapor Phase Treatment

GWSC-4 Extraction Wells with Reinjection and In-Situ Treatment

- Wells screened at varying depths to create capture
- Extracted groundwater reinjected at selected upland sites
- Addition of treatment media to reinjected water to enhance in-situ treatment
- Could be combined with NAPL alternatives, such as surfactant or water flooding
- Treated water is recaptured by shoreline extraction wells
- Recirculating Groundwater Recovery Wells with in-well treatment to be considered as an option in this alternative

GWSC-5 Monitored Natural Attenuation

- To occur in upland areas where natural attenuation is sufficient to achieve concentrations protective of in-water beneficial uses

Attachments

Figure 1	Site Location Map
Figure 2	General Gasco and Siltronic Site Features
Figures 3 through 8	Groundwater Screening Maps
Appendix A	Groundwater Screening Tables A1 through A5

6 REFERENCES

Anchor Environmental, LLC. 2001. NW Natural Gasco Site Draft Screening Level Nearshore Source Control Evaluation Results Report. Prepared for NW Natural. Seattle, Washington.

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FIGURES

ATTACHMENT A